GPM and Airborne Radar Investigations: PIA Estimation

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Introduction [1]

- The APR-2 airborne precipitation radar has been in operation since 2001, collecting data with same frequencies and geometry as DPR
- In 2015 APR-2 was augmented with W-band (referred to as APR-3)
 - Originally due for completion June of 2016
  - Accelerated schedule to accommodate OLYMPEX
- APR3 acquired data on all DC8 flights, Nov 12 – Dec 19
- Among accomplishments include two underflights of GPM for observations of precipitation
- The APR3 Ku/Ka-band channels allow direct comparison with DPR
- The W-band channel provides high resolution observations of light precipitation and clouds, allowing dual-frequency (Ka/W) retrievals

[2]

Example from November 18: Ku, Ka, W, DFR Ku/Ka, DFR Ka/W

Shallow post-frontal convection with an overrunning altostratus ice-cloud layer
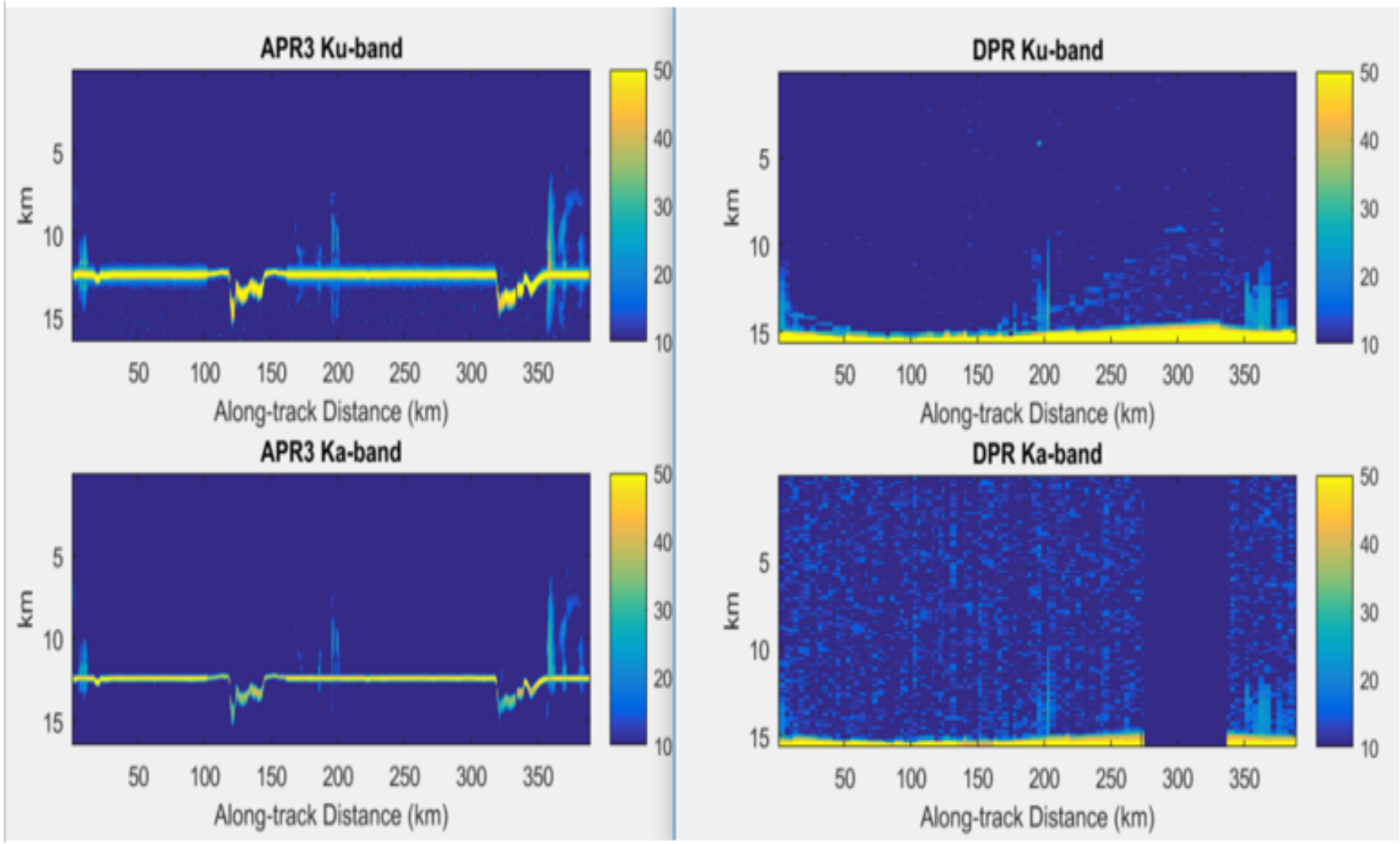

[3]
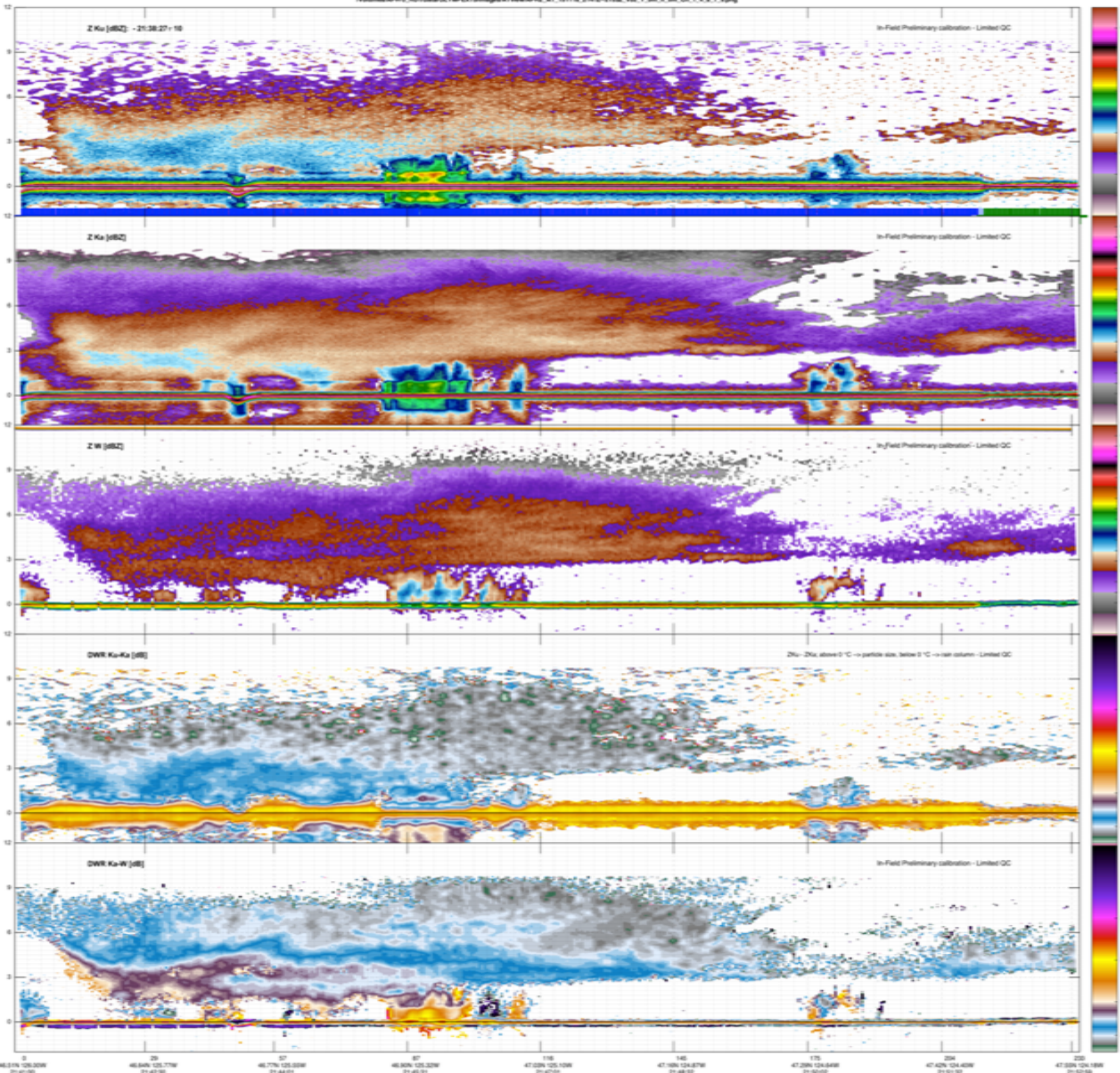
- APR-3 Ka/W DFR in ice should be indicative of ice particle size; plots below compare MASC brightness temperatures with DFR (horizontal axis is time) – Dec 3 during GPM underflight
- Generally, larger DFR is associated with lower Tb; dataset should allow multi-frequency and/or multi-instrument retrievals for comparison with GPM

MASC radiometer

APR3 W-band

Data in precip not shown

(Co-alignment of data courtesy J. Turk)

[4]
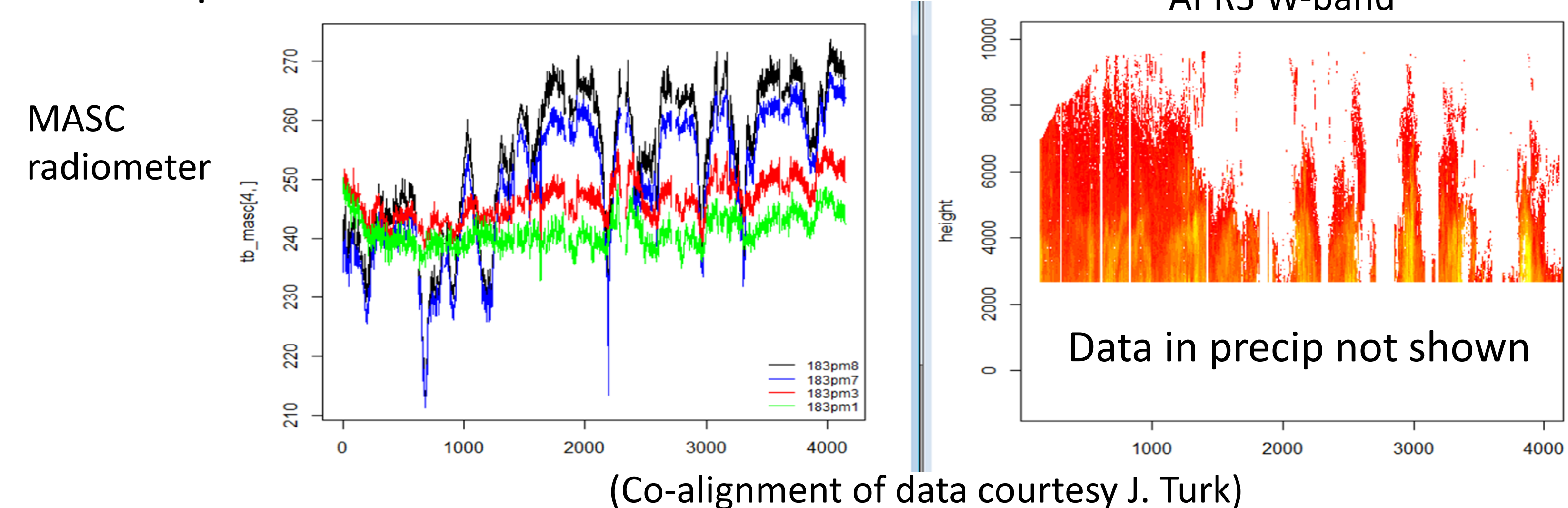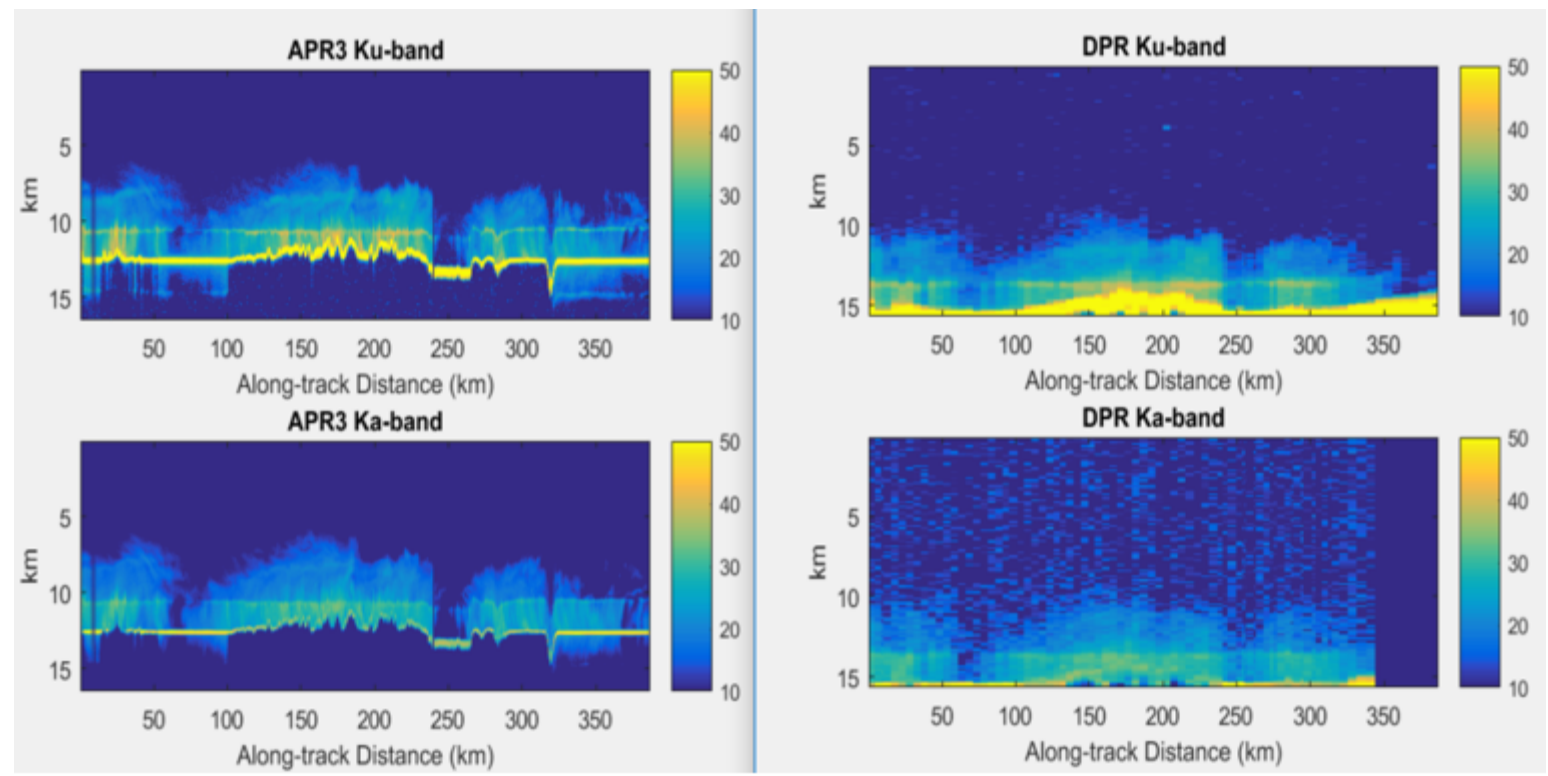
Left: data for GPM underflight Dec 3
Below: Dec19 underflight

Underflights allow direct comparison of APR3 and DPR for assessment of non-uniform beam-filling (NUBF) effects

[5]

NUBF is important to understand and correct since it causes biases in radar estimates:

- When there is NUBF, we would like to get the average of the precipitation
- Instead, we measure the average of radar reflectivity and surface backscatter
- Nonlinear relations between precipitation quantities and radar quantities cause biases when using average radar quantities to estimate average precipitation

Studies using airborne radar data show that PIA estimated with Surface Reference Technique (SRT) are especially impacted by NUBF

Right: plot of PIA Error versus standard deviation of PIA inside simulated GPM footprint (Durden & Tanelli 2008)

[6]
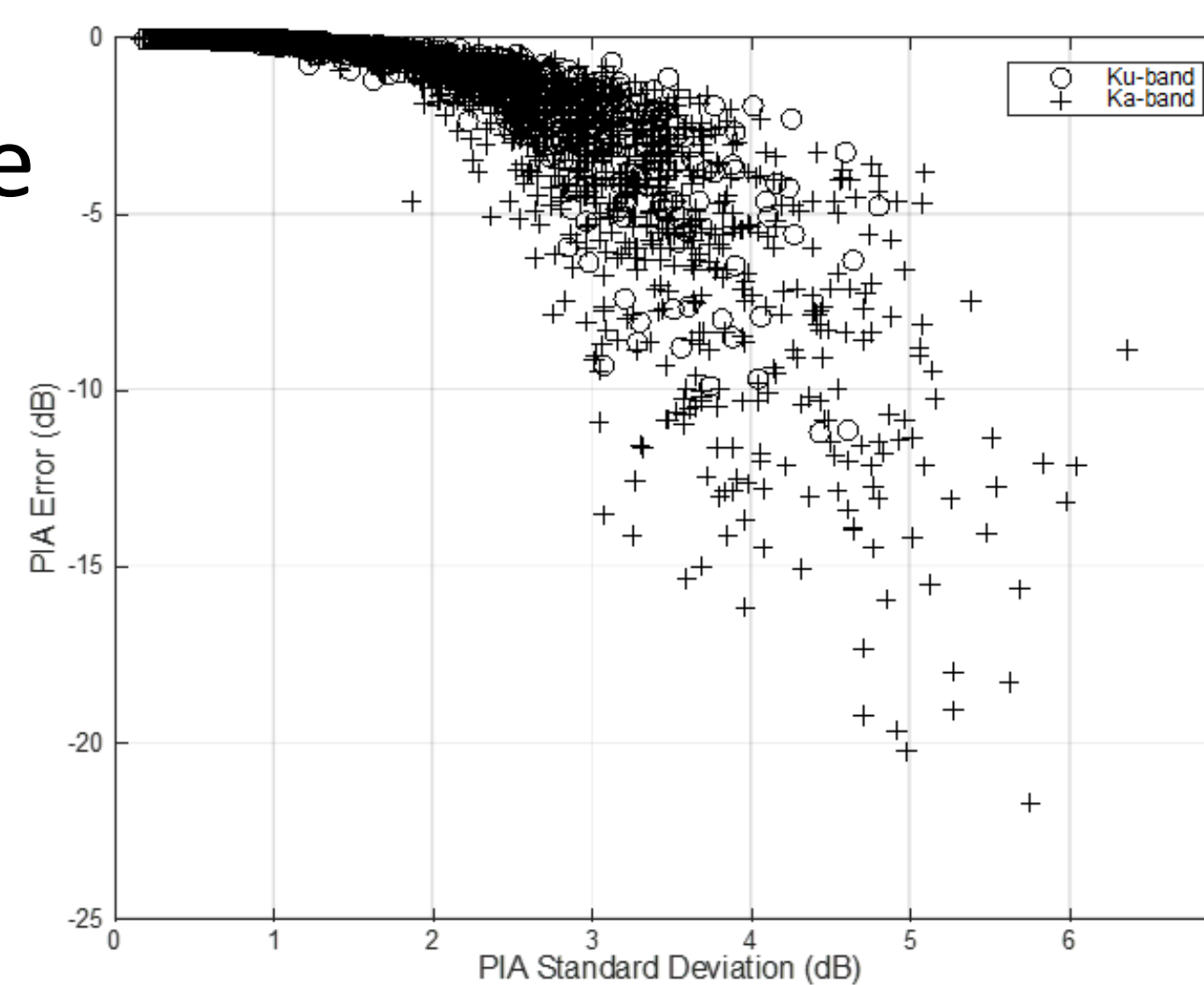
- NUBF easier to detect with DPR because NUBF changes expected ratio of the Ku/Ka PIAs
- Calculation below (left) of expected value of PIA as a function of rain rate for log-normal rain
- At right, GPM data show same behavior

Example case suggests PIA KA ~ 5 x PIA KU when NUBF is small (blue)

[7]
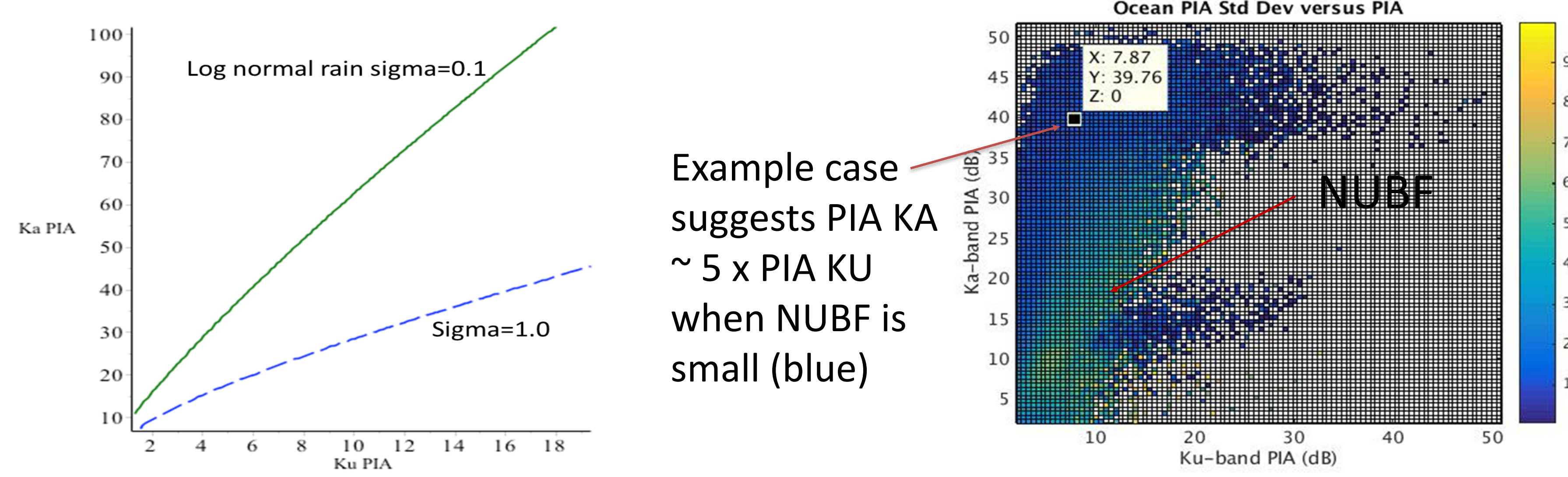
- Hence, theory, simulations, and DPR data confirm impact of NUBF on SRT-estimated PIA
- An alternative method of PIA estimation uses only the radar profile, not the surface measurement (suggested by Z. Haddad)
- Advantages:
  - Shape of vertical profile should be less impacted by NUBF
  - Could provide alternative over land, where SRT is less reliable

Why? Consider a case in which horizontal variation is the same at all altitudes; simplest example is half-filled, half-empty
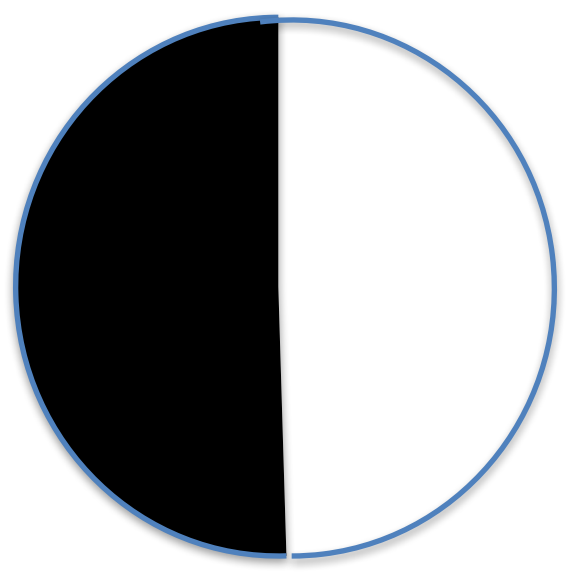
Near-surface range bins will be attenuated by the PIA due to the rain; surface bin attenuated by only 3 dB

Wind shear will violate this assumption; however, impact may be less than with SRT

[8]

To develop profile-only PIA estimate, we needed a database with known precipitation, PIA, etc; synthetic database:

- Used more than 1 year of TRMM PR reflectivity profiles
- For each profile over ocean, allow drop size distribution to vary
- Simultaneously estimate R, Zka, attenuations, PIAs
- Result: many rain profiles that are consistent with the measured TRMM Ku-band Z profile

Second approach to database: used APR Ku/Ka-band measurements over ocean convection

Synthetic database Ka PIA (vertical axis) versus measured DFR near surface (horizontal axis)

[9]
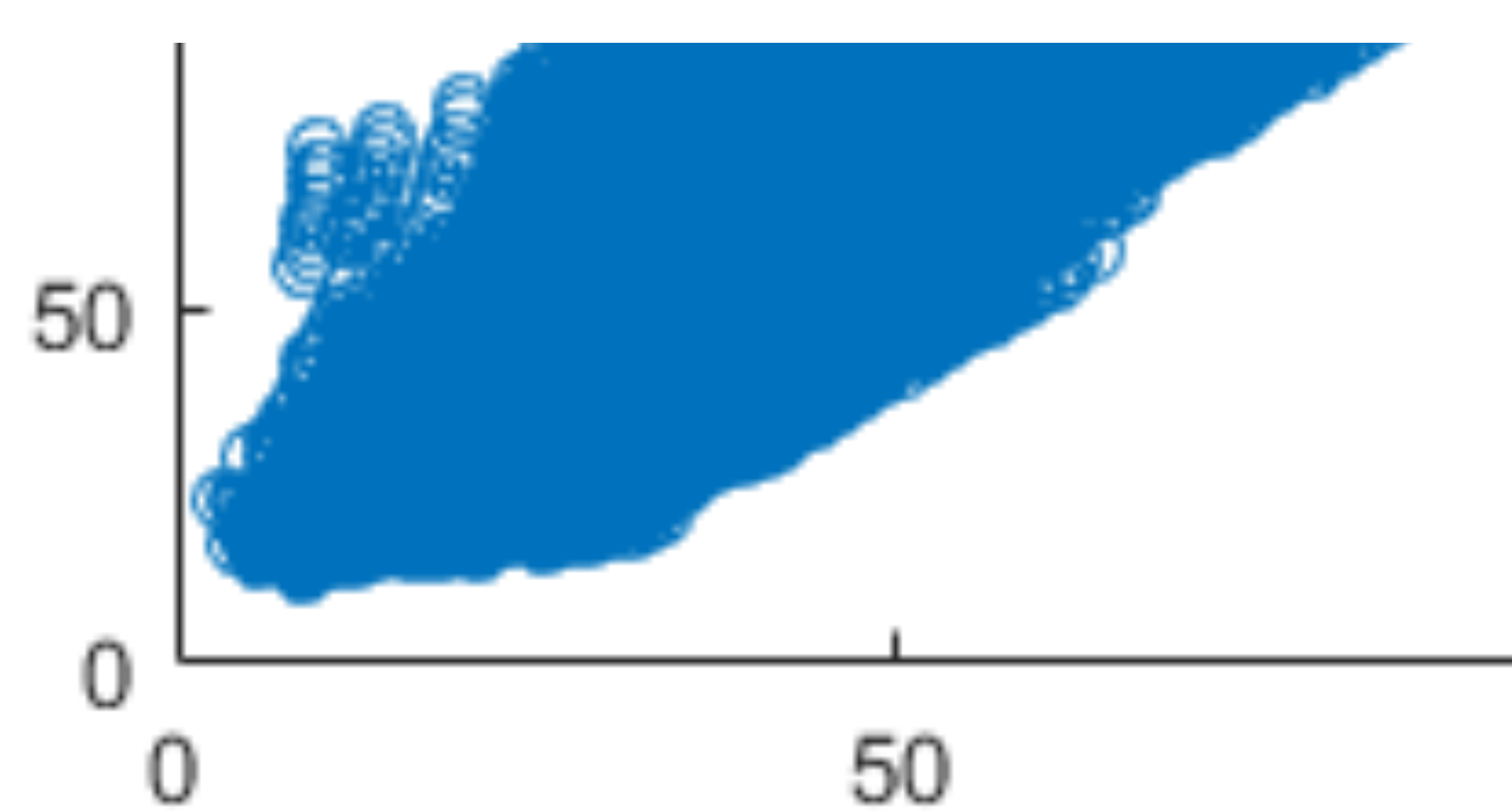
- Examined various profile shape metrics, including principal components, slope, max Z, max dual-frequency ratio (DFR)
- Best predictor of PIA is DFR near surface
- Smaller error for GPM PIA estimate when using predictor trained from APR Ku/Ka database than synthetic
- Scatter plot is Ka-band SRT PIA (vert axis) versus predicted Ka PIA for GPM cases; NUBF cases are blue
- RMS error using GPM Ka-band is 2.6 dB for cases with small NUBF
- Increases to 4.2 dB for larger NUBF (> 5 dB std dev)
- SRT bias can be 15 dB in similar cases (Durden & Tanelli 2008 and plot in panel 5, above)
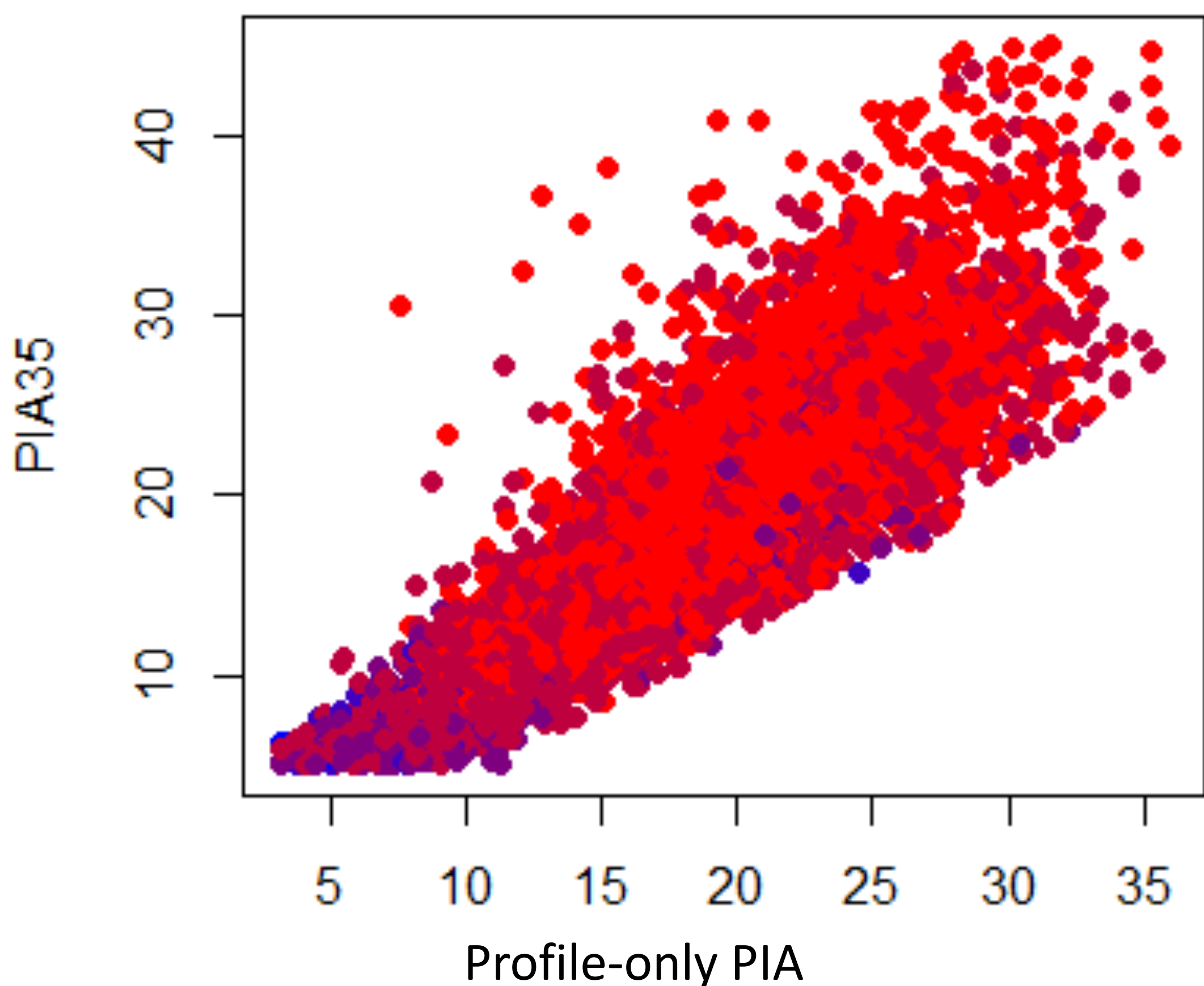
Summary [10]

- APR3 collected data set in OLYMPEX that will be useful for multi-frequency/instrument retrievals, including direct comparison with GPM
- Initial analysis of non-SRT PIA estimate indicates may be possible to predict PIA to within a few dB using only the observed reflectivity profile
- Our hypothesis is that PIA estimation from profile may have less error than SRT in cases with large NUBF
- Tests of PIA estimation using DFR near surface provides 2.6 dB RMS error at Ka-band (smaller at Ku-band)
- Error for NUBF cases is larger but likely better than SRT in some cases

- Plans: directly assess NUBF via OLYMPEX cases, further investigate utility of PIA estimation using profile-only approach